Evaluation of Sweet Whey Solids in Yellow Layer Cakes with Special Emphasis on Fragility

4677

By E.J. Guy
Eastern Regional Research Center
U.S. Department of Agriculture
Philadelphia, PA

Although large amounts of cheese whey are being processed and utilized, increases in cheese production make more whey available. From USDA statistics on cheese production, it is estimated that the total amount of fluid whey produced in the United States increased from 27 to 42 billion pounds between 1975 and 1980 (1,2). Dried whey production increased from 595 to 662 million pounds during the same period while the amount utilized by bakeries and in prepared mixes increased from 85 to 133 million pounds (3,4).

Hanning and DeGoumois (5) reported that the addition of 10 to 15% whey to cakes increased volume, tenderness, flavor, browning and keeping quality relative to cakes with no milk solids, and increased moistness and flavor relative to cakes with nonfat milk solids (MSNF). Reduction of shortening levels and addition of 15% whey solids increased volumes with total cake scores remaining essentially unchanged. DeGoumois and Hanning (6) reported that the addition of 20% dried whey to 100% sucrose cakes increased compression but not volume, whereas equivalent additions of sucrose, glucose and α-and β-lactose increased both. However, the whey, but not the sugar, improved tenderness and texture scores. Best (7) reported that, compared to 12.5% MSNF, cakes made with 10% sweet whey solids (SWS) and 2.5% MSNF at reduced sugar and shortening levels had better volumes and equal flavor and were more tender and stable to handling without being tough. Although not too well documented, experience with whey cakes oftentimes shows them to be fragile, making handling of the cake difficult.

The purpose of this study was to develop methods to measure cake fragility and to develop formulas containing SWS that produced cakes of decreased fragility and of superior height and cake score. Comparisons of the fragility of cakes with SWS and nonfat dry milk (NFDM) were also made.

Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

Materials and Methods

Flour and milk products were obtained commercially. The gross compositions of these ingredients were typical (**Table I**). Frozen pasteurized whole eggs, extra fine granulated sugar, USP lactose hydrate, special emulsified cake shortening, Fleischmann's baking powder, and single-strength vanilla flavoring were used.

Cake Baking

Two cake formulations were tested (**Table II**). The batter for the yellow cakes was mixed in a four-quart bowl with a flat paddle on a Hobart N50 mixer (**Table III**). Vanilla was blended with the egg and water mixture. The sides of pans were greased with pan grease and pan bottoms lined with pan liners. Two cakes per batter were baked in an electric, reel-type oven. After removal from the oven, the cakes were cooled for 10 minutes in the pan, turned out on a wire rack, and further cooled for two to three hours before cutting and evaluating.

Cake Evaluation

Height—As an index of volume, the height of the cut surface of a cake half at its center plus 6 and 10 cm on each side from the center was measured in millimeters using a special cake measuring template. Values of 170 mm corresponded to a specific volume (cc/g) of about 3.3 and 195 mm to a specific volume of 3.8, calculated from weights and volumes measured on these cakes.

Specific gravity—The specific gravity, expressed as g/cc, was determined by weighing freshly mixed batter at 22-23°C into a tared 58 cc plastic cup.

Firmness—Using a Baker compressimeter, compression was determined on the cakes with the No. 2 setting of the

TABLE I
Composition of Ingredients

	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	pH
Cake flour	2.4	—	8.0	0.28	4.5
NFDM*	4.7	0.76	36.8	7.49	6.5
SWS*	4.7	0.90	12.9	8.00	5.9
Demineralized SWS*	4.5	1.25	13.5	0.85	6.1

*Remainder lactose (NFDM, nonfat dry milk; SWS, sweet whey solids).

TABLE II
Cake Formulas

Formula*	1	2
Flour (14% moisture)	100	100
Sugar	115	105
Whole eggs	55	45
Shortening	50	40
NFDM	14	10
or		
SWS	10	10
Water	80	75

*All formulations also contain baking powder, salt and single strength vanilla at levels of 6, 2.5 and 0.2%, based on flour.

TABLE III
Cake Baking Procedure

(1) Mix all dry ingredients and dry blend for 3 minutes at low speed.
(2) Add one-half of eggs and water, mix 3 minutes at low speed, scraping after 0.5 and 1.5 minutes.
(3) Add remaining eggs and water; mix 0.5 minutes at low speed then 3 minutes at second speed, scraping after 0.5, 1.5 and 2.5 minutes.
(4) Mix 3 minutes at low speed.
(5) Scale 370 g into 20 cm pan.
(6) Bake at 190°C for 26 minutes.

fulcrum, and is expressed as the grams load required to depress a slice of cake one millimeter. The softest cakes have the lowest numbers. Fresh, two to three hours old, crustless 2.5 cm thick slices of cake, 6.25 cm square, were cut using a mitre box to ensure a uniform thickness. Cakes were also stored up to four days in a tightly closed cabinet (to prevent drying) at room temperature before being cut.

Scoring—Ten points each were assigned for symmetry, crumb color, crust color and grain, and 20 points for texture—one that was soft, velvety, and yet resilient. The best symmetry was uniform with a slight rise of cake in the center. Light brown uniform crust color and creamy yellow crumb color of uniform small size grain structure were judged the best. Cut portions of cakes were mounted in plastic boxes and assigned numbers to judge grain. Cakes were scored by the author.

Fragility: *Penetration*—Fresh cake slices were cut as described for the firmness tests. Four slices from each cake were subject to penetration for five seconds with the brass cone of a Precision Scientific Penetrometer. The penetration values in millimeters were read from the scale.

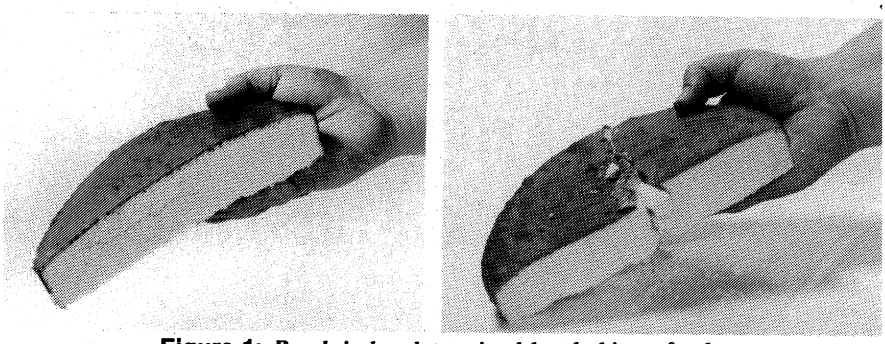

Figure 1: ***Break index determined by shaking of cake.***

Sieving—Three hour old cakes were cut into crustless 2.5 cm cubes and 12 of the weighed cubes were shaken five minutes over a four mesh screen using a Rototap. The weight percentage of the cubes passing through the screen was calculated.

Instron—Six center cuts of cake, 2.5 x 8.12 x 4.38 cm, were prepared from freshly baked samples using the mitre box to size the cut. The force applied to break the cake piece at its center was determined with a flexiclamp attachment on an Instron machine. The chart ran at 25 cm/min. The flexiclamp head moving at 12.5 cm/min produced a force of 18 kg/min.

Weight Force to Break Cakes—Freshly baked cakes, cooled two to three hours, were returned to their pans and placed inside polyethylene bags and frozen and held at -18°C. After one to three days, the frozen cakes were cut in half, then the top crust of each half was cut, yielding a flat surface to the piece. After holding at room temperature for two to three hours to thaw, the half sections were placed on the edge of the sink, exposing one half of each portion

TABLE IV
Effect of Nonfat Dry Milk Solids, Sweet Whey Solids, and Whey Components on Yellow Cake Quality*

Milk Addition	Specific Gravity (g/cc)	Height** (mm)	Compression to Depress 1 mm (g)	Comments
14% NFDM	0.81	183[a]	14.8	Good crust color and
	0.81	184	15.2	appearance and handling.
None	0.81	179[b]	16.5	No crust color, fragile,
	0.78	179	15	crumbly, sticks to paper.
10% SWS	0.81	179[b]	15	Slightly uneven crust color,
	0.85	180	12.5	slightly fragile.
9.2% Demineralized SWS	0.79	181[ab]	13.5	Symmetry slightly poor,
	0.79	181	16	soft, fragile.
7.5% Lactose	0.81	178[b]	15.8	Crust color slightly less brown
	0.79	178	12	than 14% NFDM, crumbly crust, fragile.

*Produced from Formula 1 (see Table II); averages given from two batters and two cakes from each batter.

**Different letters indicate that values are significantly different ($P < 0.05$) than others with different letters.

TABLE V
Comparison of Methods to Determine Fragility Indices of Layer Cakes* with 10% Nonfat Dry Milk Solids (NFDM) and Sweet Whey Solids (SWS)

Cake	Penetration 5 Seconds (mm)	Through 4 Mesh Screen in 5 Minutes (%)	Break Cake by Instron (Kg)	Water to Break Cake (g)	Break Index by Shaking	
					Author	10 Panelists
NFDM	243	29.2	0.39	16.9	20.9	18.1
SWS	249.5	31.5	0.40	13.2	12.4	8.7
Standard deviation	±8.9	±3.7	±.04	±3.26	±2.60	±2.84
No. replications	8	4	5	16	16	16
Significance	NS	NS	NS	>.01-<.05	<.01	<.01

*Produced with Formula 2 (see Table II).

over the edge. A 3g -100 mL plastic cup was placed on the tip end of the portion over the sink edge. Carefully holding on to the portion of the cake lying on the surface of the sink, water from the zero mark from a 50 mL burette with the stopcock fully opened was drained into the cup until the cake broke. The amount of water in milliliters required to break the cake was used as an expression of its resistance to breakage.

Break Index—Cut halves of cake were picked up in the right hand, gently holding the cake half with its long axis in a line with the arm. With the wrist held firm, the cake was slowly and uniformly shaken, making a 15 degree arc with the forearm from the elbow, counting the shakes up and down through a completed arc until the cake had broken along its short axis (**Figure 1**). Fragile cakes yield low break index numbers and cakes which resist breakage yield high numbers.

Significance of Cake Parameters

From one batter (two cakes), one measurement of specific gravity, two cake heights and scores, four compressions and two break indices were obtained. Break indices held for cakes cooled in a room between 20 and 40% relative humidity (RH). Above 40 to 45% RH, cakes became much more fragile. All broke more easily and were more difficult to differentiate. Cake measurements were statistically analyzed (6).

Organoleptic Evaluation

Cakes were judged by 15 to 20 members of the Eastern Regional Research Center, all experienced in food evaluation, using the nine-point hedonic scale (8). Fresh slices of cake, two to four hours old, were evaluated for both taste and texture. In addition, cakes were judged on a five-point scale where "1" signifys a very fine grain, very moist and tender; "2", a slightly fine grain, slightly moist and tender; "3", an acceptable grain, moistness and tenderness; "4", a slightly open grain, slightly dry and firm; and "5" a very open grain, very dry and firm. The samples were randomly presented to panelists in individual booths. Amber lighting was used and tasters were provided with rinse water. The data were statistically treated by analysis of variance and Duncan's multiple range test to determine significance of results (9).

Results

Cakes with SWS or whey components in place of NFDM or with no added milk solids were subjectively judged to be more fragile than the richly formulated cake containing 14% NFDM (**Table IV**). Also, some portions of the fragile cakes stuck to the pan liners and sides of the pan on removal. Heights of the whey and lactose containing cakes or cake with no milk solids were similar and significantly ($p < .05$) lower than the height of the 14% NFDM cake. Specific gravities and compressions of all cakes were similar. In the test formulations, 10% SWS was used because it contains the same absolute amounts of lactose and whey proteins as those present in 14% NFDM.

Since whey cakes were judged to be more fragile than those with NFDM, several methods to measure fragility were evaluated. **Table V** shows that, with a lean cake formulation containing either 10% NFDM or 10% SWS, a simple hand shake test to break the cake yielded the largest significant differences, followed by a titration test to break the cake.

Small but nonsignificant differences were found using penetration, sieving, and the Instron machine. Since large significant differences were obtained with several inexperienced panelists as well as an experienced panelist, and because of its ease and simplicity, the hand shake test was chosen as the best means to evaluate fragility.

A lean formulated cake containing 10% SWS compared favorably with the richly formulated cake with 14% NFDM in specific gravity and height, compression and break index as a measure of fragility (**Table VI**). The lean formulation cake with 10% NFDM was the largest cake and was the least fragile.

All fresh cakes compared favorably on overall hedonic taste and texture evaluation (**Table VII**). The 10% SWS cake was as moist and tender as the 14% NFDM cake and was equivalent in moistness and was more tender than the cake with 10% NFDM. However, the 14% NFDM cake had the finest grain (see also **Figure 2**).

TABLE VI
Comparison of Rich Formulated Yellow Cake With Lean Formulated Cakes*

Formula	Milk Addition	Specific Gravity (g/cc)	Height (mm)	Compression to Depress 1 mm** (g)	Break Index
1	14% NFDM	0.86	188[a]	11.4[b]	12.8[a]
2	10% NFDM	0.84	199[b]	8.9[a]	21.8[b]
2	10% SWS	0.85	194[ab]	10.1[ab]	16.5[a]

*Produced from Formulas 1 and 2, respectively (see Table II).
**Values with different letters are significantly different ($p < 0.05$).

TABLE VII
Comparison of the Panel Ratings of Rich Formulated Yellow Cake with Lean Formulated Cakes*

Formula	Milk Addition	Hedonic Taste	Hedonic Texture	Grain**	Moistness**	Tenderness**
1	14% NFDM	7.33	6.81	3.06	3.31[b]	3.17
		7.44	7.16	2.88[b]	3.16[b]	2.84[b]
2	10% NFDM	7.33	6.56	3.31	3.75[a]	3.00
		7.16	6.55	3.61[a]	3.72[a]	3.17[a]
2	10% SWS	7.40	6.93	3.12	3.43[ab]	2.75
		7.11	6.44	3.50[a]	3.38[ab]	2.84[b]

*Produced from Formulas 1 and 2, respectively (see Table II).
**Lower numbers indicate finer, moister, softer cakes. Different small letters indicate that values are significantly different ($P < .05$) and different small underlined letters indicate that values are significantly different ($P < .01$).

TABLE VIII
Effect of Storage at 23°C on Compression of Yellow Layer Cakes

Formula	Milk Solids	Compression to Depress 1 mm* (g) Days 1	2	3	4
1	14% NFDM	15.5[b]	17.5[b]	17.0	22.5
2	10% NFDM	15.5[b]	16.0[b]	18.0	22.0
2	10% SWS	11.6[a]	13.0[a]	19.5	22.0

*Different letters indicate that values are significantly different ($P < 0.05$).

TABLE IX
Effect of Combinations of Skim Milk Solids and Sweet Whey Solids on Cake Baking Quality*

Formula	NFDM (%)	SWS (%)	Specific gravity (g/cc)	Height (mm)	Compression to Depress 1 mm (g)	Break Index	Grain Score	Total Score
1	14	0	.88	185[a]	10.3	14.3[a]	8.8	55.0
2	10	0	.87	196[b]	9.8	21.7[ab]	8.5	54.0
2	3.5	6.5	.86	194[b]	10.3	26.2[b]	8.5	54.6
2	2	8	.85	195[b]	9.4	18.8[ab]	8.5	54.0
2	0	10	.87	188[a]	9.4	13.8[a]	8.5	53.8

*Average of three bakes. Different letters indicate that values are significantly different ($P < 0.05$).

Compressions of the three cakes stored at room temperature up to four days were comparable at three and four days. However, compression of the 10% SWS cake showed it to be significantly softer at one and two days than the NFDM cakes (**Table VIII**) even though it was much the same initially (**Table IX**).

Replacement of 20 to 35% of the SWS with NFDM in lean formulations produced cakes of equivalent heights and the least fragility (**Table IX**). The blend with 3.5% NFDM was significantly less fragile than cakes produced with rich formulations with 14% NFDM and the lean formulations containing 10% SWS. Its cake score was equivalent and height superior to that of the cakes produced with a rich formulation containing 14% NFDM. It was equal to or better than the lean formulation cake containing 10% NFDM with respect to height, lack of fragility and total cake score. Specific gravity and compression scores were much the same.

Discussion

Although Hanning and DeGoumois (5) reported that 10 to 15% SWS increased cake volume, their results were compared to those obtained with milk solids-free cakes. Our studies indicated that at constant absorption and formula, 10% SWS or milk solids-free cake heights were similar or lower than the height of the 14% NFDM solids cake. One has to consider in these studies that formula, mixing and scaling conditions may affect results.

The replacement of NFDM with SWS increased fragility as measured by the shaking test. That NFDM promoted handling and that SWS did not enhance fragility was shown by the fact that a milk solids-free cake was very fragile and that small amounts of NFDM in combination with larger amounts of whey solids decreased fragility (as found and reported by Best (7)). This suggests that casein or small amounts of casein along with whey components promotes breakage resistance.

Since no methods to measure fragility or handling capacity of cakes have been reported, and because this quality of cakes is very important, a subjective shaking test was devised. Even though the relative standard deviation of this break index is large, it is a simple test and does offer a means to measure moderate to large fragility differences that are exhibited by sweet whey solids containing cakes compared to cakes containing NFDM.

Compressions of cakes containing SWS or NFDM were much the same in fresh cakes and apparently do not indicate fragility differences.

Summary

Replacement of nonfat dry milk (NFDM) with sweet whey solids (SWS) produced a cake of lowered height and increased fragility. Fragility was measured by gently and uniformly shaking a cut half of cake and was expressed as the number of times the arm moved through a defined arc both up and down until the cake broke. Using SWS at a level of 10% in place of NFDM in a lean formula with reduced egg, sugar and shortening, led to cakes comparable in hedonic taste, texture, moistness, tenderness, height and fragility to those produced from a rich formulation cake with 14% NFDM. Less fragile cakes of superior height and cake score were produced with the lean formula if 3.5% NFDM and 6.5% SWS were used. All lean formula cakes had slightly poorer grain scores than that of the rich formulation cake.

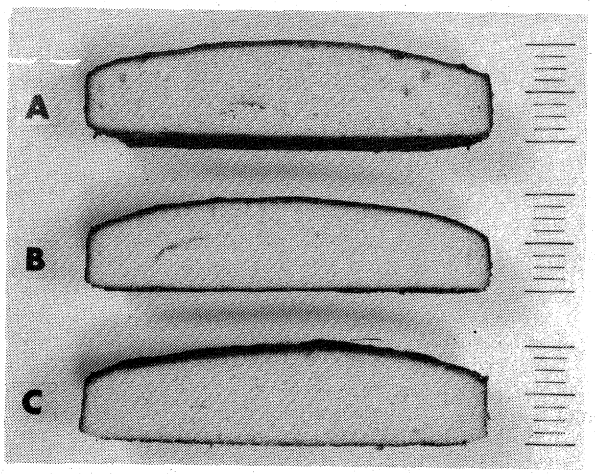

Figure 2: *Yellow layer cakes (A, 10% NFDM, Formula 2; B, 14% NFDM, Formula 1; and C, 10% SWS, Formula 2).*

Acknowledgments

Acknowledgment is given to F.B. Talley, for conducting organoleptic evaluations of cakes; to B.C. Sullivan for conducting analyses of ingredients; and J.G. Phillips, Consulting Statistician, Northeastern Region, Agricultural Research Service, U.S. Department of Agriculture, for statistical evaluations.

References

(1) Delaney, R.A.M. Proceedings Whey Products Conference, 1978. p. 111. (1979).
(2) Dairy Products Annual Summary. 1980. USDA. Da. 2-1(81). June, 1981.
(3) Whey Products. A Survey of Utilization and Production Trends. 1975. Whey Products Institute. 1976.
(4) Whey Products. A Survey of Utilization and Production Trends. 1980. Whey Products Institute. 1981.
(5) Hanning, F., and DeGoumois, J. *Cereal Chem.* 29:176 (1952).
(6) DeGoumois, J., and Hanning, F. *Cereal Chem.* 30:258 (1953).
(7) Best, B. *Bakers Digest* 41:38 (1967).
(8) Peryam, D.R., and Pilgrim, F.V. *Food Technol.* 11:9 (1957).
(9) Snedecor, G.W. Statistical Methods, 5th ed., Iowa State College Press. Ames, Iowa (1959).